Trust, Primary Commodity Dependence and Segregation*

Arne Schollaert and Dirk Van de gaer†

Abstract

Many third world countries seem to fail to create a growth-promoting and peaceful institutional framework and are plagued by ethnic, religious or social conflict. This paper focuses on the impact of primary commodities on group behavior and, thus, on the nature of the resulting societies. Strategies are analyzed in a basic one-shot game with two players and two strategies, in which priors vis-a-vis the other player matter. We show that poverty, foreign interference and trust influence a group's willingness to cooperate. Under some circumstances (partial) segregation and (political) strife prove to be utility-maximizing and equilibrium strategies.

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†Sherppa, Ghent University. E-mail: arne.schollaert@UGent.be; dirk.vandegaer@UGent.be.

1 Introduction

The past decade developed a vast literature, both theoretical[1] and empirical[2], on the possible causes of the lack of third world economic growth. So far at least 90 different variables have been tested empirically for their influence on economic growth (Durlauf & Quah [1999]). There is, however, still no consensus on which factors determine economic growth, and thus, on which variables are responsible for the lack of growth in certain countries and regions.

In the growth literature, literacy, investments in schooling and health care, macroeconomic stability, political stability, openness to trade, investments in research and development, property rights protection, core infrastructure, . . . , are repeatedly cited as determinants of economic growth. This suggests that institutions matter. Presumably, the institutional framework[3] in many of the third world economies lacks those fundamentals (e.g. incentive structures, core infrastructure, openness) that are conducive to economic growth. A crucial question then becomes what determines the outlook of this framework.

In this context, two branches of the development/growth literature are of particular interest. First, the negative impact of resource-*booms* on the economic performance of a country is more or less viewed as a stylized fact: theoretically, both the 'Dutch disease' idea and the 'rent-seeking' literature emphasize the negative impact of resource booms on economic performance. Moreover, *"empirical studies have shown that this curse* [the curse of natural resources] *is a reasonably solid fact"* (Sachs & Warner [2001], p. 837).

The 'Dutch disease' idea argues that, due to the terms of trade windfall, natural resource booms entail a shift in production, unfavorable to the non-resource tradeable sectors. By assuming (more) 'learning by doing' (van Wijnbergen [1984]) or 'increasing returns to scale' (Sachs & Warner [1999]) in the non-resource tradeable sectors, it follows that natural resource booms frustrate growth.

The rent-seeking literature, on the other hand, emphasizes the impact of natural resource booms on the relative returns to rent-seeking activities (Tornell & Lane [1999], Baland & Francois [2000], Torvik [2002]). The limited supply of natural resources requires restricted access, thereby (potentially) creating excess rents and, thus, stimulating/inciting rent-seeking. Moreover, since natural resource *booms* increase relative returns to rent-seeking, they will, assuming that rent-seeking is costly (Murphy et al. [1991, 1993]), impede growth.

Furthermore, a fascinating debate on the importance of ethnic diversity is still ongoing. Some state that ethnic diversity within a centrally governed region tends to reduce growth, while others argue that the influence of ethnic diversity depends on the political framework.

Easterly & Levine [1997] find empirical support for the negative effect of ethnic diversity on policy choices. They argue that *"ethnic diversity encourages the adaptation of growth-retarding policies that foster rent-seeking behavior and makes it more difficult to form consensus for growth-promoting public goods"* (p. 1207). Alesina et al. [1999] too find support for the detrimental impact of ethnic diversity on growth. By using a majority-voting model, they show that voting on, first, the amount of taxation and, second, the type of public good results in fewer investments in core public goods for a higher 'median distance to the median voter' (which reflects the polarization of preferences). Moreover, their empirical analysis corroborates these findings.

Instead, Collier [1998, 2001] argues that the institutional and political framework matters. The author makes a distinction between 'ethnic dominance' and 'ethnic fractionalization' and shows, both empirically and with a majority-voting model, that *"ethnically diverse democracies do not have worse economic performance and are actually safer than homogenous societies"* (Collier [2001] p. 153).

[1]Solow [1956], Romer [1986], Mankiw et al. [1992], . . .

[2]Barro [1996], Benhabib & Spiegel [1994], Sachs & Warner [1997], Edwards [1998], . . .

[3]Note that, when talking about institutions, we refer to the definitions used by North [1978].

Like Tornell & Lane [1999], the model we present allows us to link these two branches of the literature. The mechanism described here, however, differs considerably from theirs. In their model, groups decide on the fiscal transfers they extract and on the allocation of their capital stock. In contrast, we present a simple one-shot-game, in which two groups, in order to maximize *own group utility*, decide on whether or not to cooperate with each other. In this, the strategy-choice depends on, among other things, the degree of resource dependence of the economy and the level of trust among groups. Note, furthermore, that in contrast to the mainstream 'natural resource'-literature, we do not merely focus on resource *booms*: our model allows to analyze the impact of both the degree of resource dependence and shocks in this degree.

Our model aims at linking primary commodity dependence and social group diversity to the outlook of the institutional framework[4]. We consider a country inhabited by two social groups and show that primary commodity dependence could influence group strategy. By using basic game theoretic principles we show that a fully integrated society, where both groups choose the cooperative strategy, is but one of the four possible equilibrium outcomes: (partially) segregated societies with either of the two groups dominating and a conflictual society are the other outcomes[5]. This means that under some circumstances rent-seeking from at least one of the groups (in our model we call it *fighting*) or segregation proves to be utility maximizing and even an equilibrium group strategy. This could explain some of the poor policy choices we observe in (many) third world countries.

In section 2 we formalize the basic assumptions and the corresponding payoffs of the model. Section 3 analyses the Nash equilibria that arise for different parameter values, while in section 4 we discuss the impact of trust on the resulting equilibria when beliefs are unconfirmed. Finally, section 5 presents our conclusions.

2 Assumptions and payoffs

2.1 Assumptions

Let N be the population at working age in the region. αN is the size of the population belonging to group K and $(1-\alpha)N$ is the size of the population belonging to group L.

Moreover, we assume that the economy contains two types of 'activity': *rewarding jobs* and *subsistence jobs*. Every *rewarding job* generates a high net income, $Y_R(>0)$; the *subsistence jobs* generate a net return normalized to be equal to zero, $Y_S(=0)$. A crucial variable in the model will be the proportion of rewarding jobs in the economy, $r \in [0,1]$. We assume that all people belonging to N are employed in either of the two types of jobs. Hence, national income is assumed to be: $ni = rY_RN$.

Furthermore, both groups are assumed to have the following strategy space: either they choose to cooperate (C) with the other group, or they choose to fight (F). The *cooperative* strategy reflects the fact that the group chooses not to favor members of the same group and integrates and interacts with the other group. The *fighting* strategy on the other hand, should not necessarily be interpreted in a strict sense; it just means that the group *is* willing to spend resources (cf. infra) in order to protect and privilege its members or deems it lucrative to pursue segregation. This results in four potential outcomes of the game: (C,C) when both choose to cooperate; (F,C) when K chooses to fight while L chooses to cooperate; (C,F) when the reverse holds and (F,F) when both choose not to cooperate. The following table shows the nature of the corresponding societies:

[4]It is important to keep in mind that we use 'social group diversity' as a very broad concept: it ranges from ethnic diversity or polarization to social class stratification.

[5]Note that the conflictual society will, after a strife for power between the two groups, also result in a (partially) segregated society.

(C, C): fully integrated society	(C, F): (partially) segregated society (L dominates)
(F, C): (partially) segregated society (K dominates)	(F, F): conflictual society

Since the fighting option implies that the group decides to spend resources to assure that the rewarding jobs are primarily granted to the group members, it generates a cost. If just one of the two groups chooses not to cooperate, we assume that the rewarding income is reduced to $\delta_1 Y_R$, with $0 < \delta_1 < 1$. This implies that national income decreases to $r\delta_1 Y_R N$. This can reflect a wide range of potential costs of non-cooperation, e.g., the misallocation of resources (less trade, misallocation of talent), the negative incentive effects of nepotism and discrimination, the impact of antagonism between groups on the (over-) exploitation of common resources, a lower social capital stock, ... Moreover, if two groups decide not to cooperate, costs will be assumed to be even higher since this situation could also generate costs of conflict (or even civil war). The rewarding income is assumed to be reduced to $\delta_1\delta_2 Y_R$, with $0 < \delta_2 < 1$ ($ni = r\delta_1\delta_2 Y_R N$).

It is important to note that we will assume that agents are risk neutral: their utility function is linear in income. Moreover, we assume that there is no coordination problem or free riding within a group.

Finally, we include a variable P (resp. $[1 - P]$) that reflects the probability that when no one cooperates the members of group K (resp. L) will manage to 'capture' the rewarding jobs.

2.2 The payoff matrix

The payoffs of the game are summarized in the matrix below. Let $H \in \{K, L\}$ and $X, Y \in \{C, F\}$. $u_H(X, Y)$ then represents the payoff of player H[6] if player K plays strategy X and L plays strategy Y. Note that $u_H(F, F)$ is player H's expected payoff, since the actual payoff is a random variable in this case (see the definition of P).

	L	
K	$u_H(C, C)$	$u_H(C, F)$
	$u_H(F, C)$	$u_H(F, F)$

In this setting r will turn out to be one of the crucial parameters. Due to symmetry between the case where $1 - \alpha < \alpha$ and $\alpha < 1 - \alpha$, we can limit the number of cases down to eight: $(1 - \alpha) = \alpha = 1/2 < r$ $\|$ $(1 - \alpha) = \alpha = r = 1/2$ $\|$ $r < (1 - \alpha) = \alpha = 1/2$ $\|$ $(1 - \alpha) < \alpha < r$ $\|$ $(1 - \alpha) < \alpha = r$ $\|$ $(1 - \alpha) < r < \alpha$ $\|$ $(1 - \alpha) = r < \alpha$ en $r < (1 - \alpha) < \alpha$.

Here, however, we focus on the situations where $(1 - \alpha) < \alpha < r$, $(1 - \alpha) < r < \alpha$ and $r < (1 - \alpha) < \alpha$. These three cases incorporate all the important aspects of the model; the remaining five do not add any essential new insights. For the sake of completeness, those five cases are analyzed in A.

3 Nash equilibria

In this section we focus on the existence of Nash equilibria. The concept of a Nash equilibrium is particularly interesting in our context for it is a *strategically stable* and *self enforcing* equilibrium

[6]Following the 'no-free-riding' assumption we can state that the strategy of a player is the same as the group strategy.

(Mas-Colell et al. [1995], p. 249). Hence, it can be used as a 'criterion of stability'.

Formally, we talk about a Nash equilibrium when there is an equilibrium in *actions* and *beliefs* (Varian [1992], p 265): a player K (resp. L) has probability beliefs, π_L (resp. π_K), about the strategy of L (resp. K) and chooses a certain strategy with probability p_K (resp. p_L). For a Nash equilibrium we need that beliefs are correct, i.e. $p_K = \pi_K$ and $p_L = \pi_L$, and that each player is choosing his p so as to maximize his expected utility given his *beliefs*. Clearly, these are relatively strong conditions. Therefore, in section 4 we propose an alternative approach to analyze the existence of equilibria.

A Nash equilibrium in pure strategies is a special case of a Nash equilibrium: each player's probability of playing one particular strategy is 1. So, a Nash equilibrium in pure strategies is a strategy pair (X^*, Y^*) so that $u_K(X^*, Y^*) \geq u_K(X, Y^*)$ and $u_L(X^*, Y^*) \geq u_L(X^*, Y)$ for all $X, Y \in \{C, F\}$.

In the next paragraph we shall analyze which Nash equilibria in pure strategies arise for varying parameter values $(P, r, \delta_1, \delta_2)$. Note that (at least for now) we suppose that P is exogenous. This enables us to analyze the impact of, for example, external[7] interference (ΔP) by using simple comparative statics.

3.1 The payoffs

Case 1: $(1-\alpha) < \alpha < r$**.** The economy has more rewarding jobs than there are people in either group, which means that if one group dominates[8], some randomly assigned members of the other group will still be granted a rewarding job.

The (per capita) payoffs are:

$$\begin{array}{ll}
u_K(C,C) = rY_R & u_L(C,C) = rY_R \\
u_K(C,F) = \left[\frac{r-(1-\alpha)}{\alpha}\right]\delta_1 Y_R & u_L(C,F) = \delta_1 Y_R \\
u_K(F,C) = \delta_1 Y_R & u_L(F,C) = \left[\frac{r-\alpha}{1-\alpha}\right]\delta_1 Y_R \\
u_K(F,F) = \left[\frac{P\alpha+(1-P)[r-(1-\alpha)]}{\alpha}\right]\delta_1\delta_2 Y_R & u_L(F,F) = \left[\frac{(1-P)(1-\alpha)+P(r-\alpha)}{(1-\alpha)}\right]\delta_1\delta_2 Y_R
\end{array}$$

Obviously, the values of δ_1 and δ_2 will determine the types of equilibria that arise. Both the relative size of r and δ_1 and the relative size of δ_2 and its critical value for each player, CV_H, matters. CV_H is the 'critical' value of δ_2 for which player H is indifferent between his two strategies when the other player fights. It is defined as follows:

$$\begin{array}{lcl}
CV_K = \hat{\delta}_{2_K} & : & u_K(C,F) = u_K(F,F) \\
CV_L = \hat{\delta}_{2_L} & : & u_L(F,C) = u_L(F,F).
\end{array}$$

This means that CV_K and CV_L take the following values:

$$\begin{array}{rcl}
CV_K & = & [r-(1-\alpha)]/\big[P\alpha + (1-P)[r-(1-\alpha)]\big] \\
CV_L & = & (r-\alpha)/\big[(1-P)(1-\alpha) + P(r-\alpha)\big].
\end{array}$$

Since $(1-\alpha) < \alpha < r$ we know that $CV_K, CV_L \in]0,1]$.

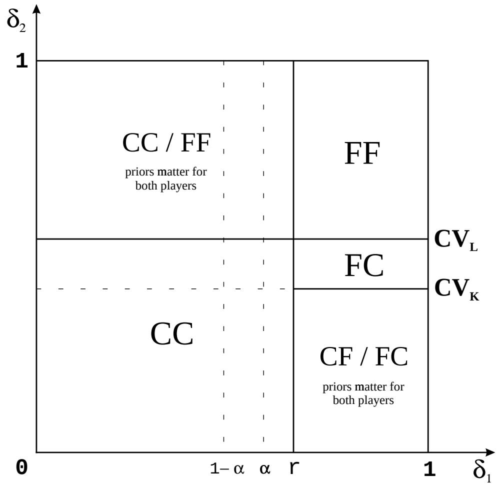
In figure 1 we trace out the respective types of Nash equilibria in pure strategies. We draw the case in which $CV_L > CV_K$[9].

[7]Think, for example, of troops from Zimbabwe, Angola, ... intervening to support the Kinshasa regime against Uganda-backed rebellion in August 1998 in the Democratic Republic of the Congo (formerly called Zaïre).

[8]Dominance reflects the situation in which one group manages to seize political and economic power. In the present context this means that the *dominant* group is in control of the rewarding jobs.

[9]$P = (\alpha + r - 1)/(2r-1) \Rightarrow CV_K = CV_L$; $P > (\alpha + r - 1)/(2r-1) \Rightarrow CV_L > CV_K$.

Figure 1: $(1-\alpha) < \alpha < r$



We can see that for sufficiently low values of δ_1 and δ_2 the cooperative equilibrium (a fully integrated society) will come about. For high values of both δ_1 and δ_2 the non-cooperative equilibrium (a conflictual society) results. When δ_1 is low and δ_2 is high, there will be two potential Nash equilibria in pure strategies: either both cooperate or both fight ($K_C|L_C$ or $K_F|L_F$ and $L_C|K_C$ or $L_F|K_F$). For high values of δ_1 and low values of δ_2, there are two other potential Nash equilibria in pure strategies: either K cooperates and L fights, or K fights and L cooperates ($K_C|L_F$ or $K_F|L_C$ and $L_C|K_F$ or $L_F|K_C$), which results in a partially segregated society, with respectively L or K dominating. Finally, for values of δ_2 between CV_K and CV_L, there will always be two pure strategy Nash equilibria: for low values of δ_1 mutual cooperation will arise, for high values of δ_1 either K or L will cooperate, while the other will fight. Who cooperates will depend on the relative size of their respective *critical values* for δ_2 (cf. infra). We shall interpret these findings in section 3.2.

Note that $\partial CV_K/\partial P < 0$, $\partial CV_L/\partial P > 0$ and that for $P = 1$, $CV_K = (r-1+\alpha)/\alpha$ $[> 0; < 1]$ and $CV_L = 1$ and for $P = 0$, $CV_K = 1$ and $CV_L = (r-\alpha)/(1-\alpha)$ $[> 0; < 1]$. In the area where $\delta_1 < r$ this implies that both when $P \to 1$ and when $P \to 0$, the CC-area is extended, since either CV_K or $CV_L \to 1$. This non-monotonous impact a change in P has on the equilibrium-areas, derives from the fact that ΔP affects CV_K and CV_L oppositely and the fact that extreme values of P (0/1) cancel one player's ex ante probability to win the 'fight'.

Furthermore, for $r < \delta_1$, the value of P will determine both the extent of the FF-area and the type of equilibrium that arises between CV_K and CV_L: when $CV_K < CV_L$, strategy FC is the unique Nash equilibrium in pure strategies and when $CV_L < CV_K$, strategy CF is the unique Nash equilibrium in pure strategies.

In two areas in figure 1 there could also exist Nash equilibria in mixed strategies: the top left area ($TL : \delta_1 < r \cap CV_L < \delta_2$) and the bottom right area ($BR : r < \delta_1 \cap \delta_2 < CV_K$). However, in this paper we will not consider these Nash equilibria in mixed strategies. Instead, in section 4 we shall provide an alternative approach to interpret these areas.

Case 2: $(1-\alpha) < r < \alpha$. The proportion of rewarding jobs lies in between the size of the two groups. This is an asymmetric case: if K dominates, all members of L and even some members of K will end up with a subsistence job. If, alternatively, L dominates, all members of L and some members of K will get a rewarding job.

The (per capita) payoffs are:

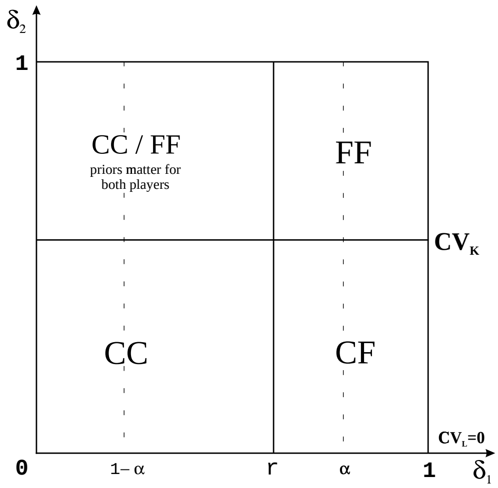
$$
\begin{array}{ll}
u_K(C,C) = rY_R & u_L(C,C) = rY_R \\
u_K(C,F) = \left[\frac{r-(1-\alpha)}{\alpha}\right]\delta_1 Y_R & u_L(C,F) = \delta_1 Y_R \\
u_K(F,C) = \left[\frac{r}{\alpha}\right]\delta_1 Y_R & u_L(F,C) = 0 \\
u_K(F,F) = \left[\frac{Pr+(1-P)[r-(1-\alpha)]}{\alpha}\right]\delta_1\delta_2 Y_R & u_L(F,F) = (1-P)\delta_1\delta_2 Y_R
\end{array}
$$

From these payoffs we calculate the values for CV_K and CV_L:

$$
\begin{aligned}
CV_K &= [r-(1-\alpha)]/\big[Pr+(1-P)[r-(1-\alpha)]\big] \\
CV_L &= 0.
\end{aligned}
$$

Here, the relative size of δ_1 to r and the relative size of δ_2 to CV_K determine the equilibria[10]. Furthermore, since $\partial CV_L/\partial P = 0$, shocks in P only affect CV_K, which induces a monotonous relation between the value of P on the equilibrium outcomes: $\partial CV_K/\partial P < 0$.

Figure 2: $(1-\alpha) < r < \alpha$



The equilibria are similar to those obtained in the previous case, with one exception: $CV_L = 0$, which implies that for high values of δ_1 player L (the smaller group) will always choose to fight. For high values of δ_1 and low values of δ_2 player K will choose to fight only when L chooses to cooperate and will choose to cooperate only when L chooses to fight. This implies that there will be just one Nash equilibrium in pure strategies: (C, F).

Case 3: $r < (1-\alpha) < \alpha$. Finally, we consider the case where the proportion of rewarding jobs is insufficient to cover either of the two groups, which means that whatever group dominates, some members of that group will not be given a rewarding job.

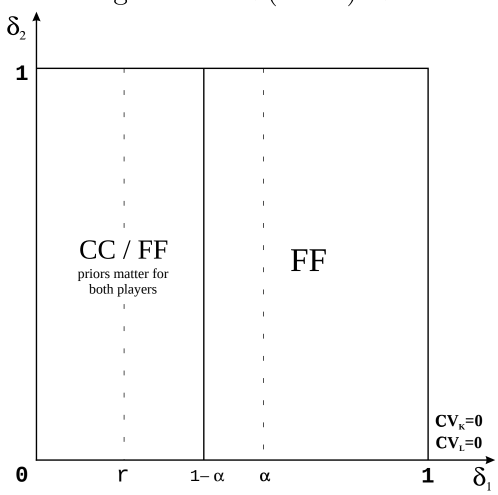
[10] Note that by construction the analysis is symmetrical with respect to K and L.

The (per capita) payoffs are:

$$\begin{array}{ll} u_K(C,C) = rY_R & u_L(C,C) = rY_R \\ u_K(C,F) = 0 & u_L(C,F) = \left[\frac{r}{1-\alpha}\right]\delta_1 Y_R \\ u_K(F,C) = \left[\frac{r}{\alpha}\right]\delta_1 Y_R & u_L(F,C) = 0 \\ u_K(F,F) = \left[\frac{Pr}{\alpha}\right]\delta_1\delta_2 Y_R & u_L(F,F) = \left[\frac{(1-P)r}{1-\alpha}\right]\delta_1\delta_2 Y_R \end{array}$$

The critical values, CV_K and CV_L, are both 0, such that the value of P does not matter for the equilibrium outcomes. With r insufficient to provide everyone of the 'winning' group with such a job, we can see that the relative size of δ_1 to $(1-\alpha)$ becomes crucial: with $\delta_1 > (1-\alpha)$, the only possible Nash equilibrium is the mutual fighting one, (F,F). With $\delta_1 < (1-\alpha)$, there are two potential Nash equilibria in pure strategies: either both cooperate or both fight.

Figure 3: $r < (1-\alpha) < \alpha$



3.2 Overview of the model

We can distinguish six areas in the model: two in which the equilibrium is – so far – undetermined (TL and BR)[11], and four in which just one equilibrium results[12] from the one-shot game: $\delta_1 < r \cap \delta_2 < CV_K$ (BL); $\delta_1 < r \cap CV_K < \delta_2 < CV_L$ (ML); $\delta_1 > r \cap \delta_2 > CV_L$ (TR) and $\delta_1 > r \cap CV_K < \delta_2 < CV_L$ (MR). This shows that case 1 can be viewed as 'the general case': case 2 contains only four areas (ML and MR disappear), and case 3 contains just two areas, TL and TR. Therefore we can focus on case 1.

Before turning to the analysis of TL and BR, we briefly summarize the three properties that make up the core of the model presented so far. We shall also discuss these properties intuitively.

First, from figures 1, 2 and 3 we see that the size of the respective areas depends on – among other things – the size of r relative to α: for $r > (1-\alpha)$, a rise in r generates a larger CC-area[13], while for $r < (1-\alpha)$, marginal changes in r have no effect. However, when a change in r causes r to shift from $<$ to $>$ $(1-\alpha)$, structural changes in the possible equilibria result.

[11]These areas will be discussed in section 4.

[12]Remark that the way the equilibrium is realized, differs according to the area: in BL and TR, both players play their dominant strategy. In ML and MR, on the other hand, the fact that for one player a certain strategy is strictly dominated, implies that for the other player too one strategy becomes 'dominant'.

[13]$\partial CV_K/\partial r \geq 0$; $\partial CV_L/\partial r \geq 0$.

This is a particularly interesting point if we interpret $(1 - r)$ as the proportion of poor or indigent people in the country, with at the one extreme a fully dispersed national income $(r \to 1)$ and at the other extreme a fully concentrated national income $(r \to 0)$. This would imply that a country with a highly concentrated national income is characterized by few rewarding jobs, while a country with a highly dispersed national income contains many rewarding jobs[14]. Then, in case 1 and 2, a reduction of 'poverty' $(\Delta r > 0)$ would increase the range of parameter values δ_1 and δ_2 for which a mutual cooperation equilibrium or, otherwise stated, a fully integrated society could come about. Therefore, even for lower costs of non-cooperation (higher δ's), a country with a low degree of poverty could still reach full integration.

Second, δ_1 and δ_2 establish the relative attractiveness of the strategies. Thus, exogenous shocks in these δ's can change equilibrium strategies: if a – large enough – negative shock in δ_1 and δ_2 would hit an economy, the country could experience a regime shift and evolve from, for example, the FF equilibrium to the CC one. In other words, if the fighting option gets more costly, cooperating could become the appropriate strategy for both players, which is a very intuitive result.

In this interpretation, if a country with a high δ_1 and δ_2 attempts to reach the cooperative solution, it will – among other things – need a high r or, vice versa, a country with a low r will require low δ's in order to reach cooperation. Intuitively, this means that a country in which fighting does not really harm national income will require a low degree of poverty, such that many people lose from non-cooperation, in order to reach a cooperative equilibrium. Now, if we assume that exploitation or civil war are more harmful/detrimental to the national product of a connected, diversified and service-industry oriented economy than to the national product of a 'primary-commodity-dependent' economy[15] (the latter is characterized by higher δ's), the analysis shows that for the latter to reach full integration, it will require a higher r, i.e. a more 'dispersed' national income and less poverty.

Third, although assumed exogenous, P plays a fascinating role, depending on the size of r relative to α: in case 1, $\Delta P > 0$ shifts CV_L up and CV_K down, which implies that when either $P \to 1$ or $P \to 0$ the CC-area is extended. In case 2, $\Delta P > 0$ still shifts CV_K down, but $CV_L = 0$, which implies that the CC-area gets smaller. Finally, in case 3, $\Delta P > 0$ has no effect, at least not in the 'unique Nash-equilibrium' areas (cf. section 4).

If we interpret P as a measure of relative power of one group (here we assumed group K), this analysis can generate valuable insights: in a country with a low degree of poverty $((1 - \alpha) < \alpha < r)$, extreme relative power ($P \to 0$ or $P \to 1$) maximizes the area that evokes mutual cooperation. In a country with an intermediate degree of poverty $((1 - \alpha) < r < \alpha)$ the 'cooperative area' grows with the relative power of the minority (group L in this case).

Clearly, within this model, P seems to be an obvious channel through which interested parties could try to manipulate the outcome of the game. Intervention by foreign governments or multinationals could change relative power, hence equilibrium strategies. However, the preceding analysis should indicate that such 'intervention', although (ideally) bona fide, can have non-trivial effects.

4 Trust and 'out-of-equilibrium beliefs'

In this section we shall have a closer look at the impact of δ_1 and δ_2 on the chosen strategy of the players in the two areas in which multiple Nash equilibria exist: TL and BR. Again, the three cases differ: case 1 contains two areas with multiple Nash equilibria (TL, BR) while in

[14]Note that in the analysis we do not make any assumptions on the level of the *rewarding income*.

[15]By primary-commodity-dependent we mean that a substantial proportion of national income is generated by natural resource extraction, e.g. mining.

case 2 and case 3 only TL remains. The following analysis, however, holds regardless of the case we consider. Hence, from here on we will only distinguish between TL and BR.

4.1 Priors

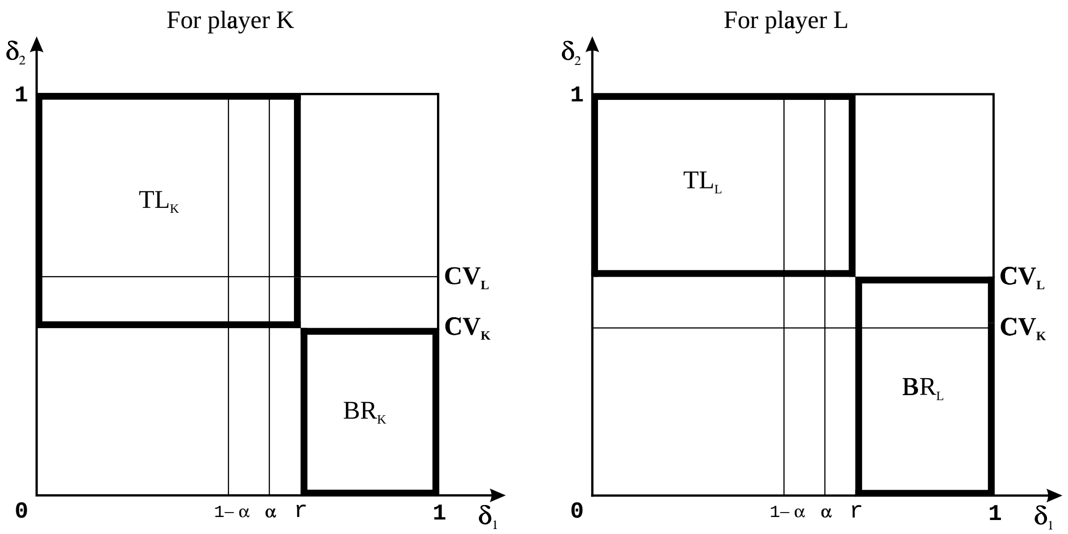
The analysis in the previous section exposes the rather 'demanding' nature of the concept of Nash equilibria (both in pure and in mixed strategies): one needs an equilibrium in actions *and* beliefs (cf. section 3).

In order to 'relax' this concept, we introduce *priors*: let π^e be the priors or beliefs players have over the other player's willingness to cooperate, and π^* the value of π^e for which a player is indifferent between his own two strategies. Then (in our model), for a Nash equilibrium, $\pi^e = \pi^*$ is a necessary – but not even sufficient – condition. Obviously, this is not a trivial condition.

In a dynamic setting, one could indeed argue that in the long run π^e would be evolving towards π^* (cf. Coate & Loury [1993]). However, even then it seems reasonable to expect some inertia in the adaptation process, which would mean that, at least in the short term, π^e could certainly differ from π^*. In contrast, in a one shot game in which priors are exogenous, assuming that $\pi^e = \pi^*$ holds would seem a rather strong assumption. The following framework allows π^e to differ from π^*.

The areas where priors matter are TL and BR: i.e. the combination of values of δ_1 and δ_2 for which the strategy of *both players* depends on their respective priors. As we can see from figure 4, for player K priors matter in $TL_K : \delta_1 < r \ \cap \ CV_K < \delta_2$ and in $BR_K : r < \delta_1 \ \cap \ \delta_2 < CV_K$ while for player L priors matter in $TL_L : \delta_1 < r \ \cap \ CV_L < \delta_2$ and in $BR_L : r < \delta_1 \ \cap \ \delta_2 < CV_L$. Only the intersection of these areas ($TL_K \ \cap \ TL_L : TL$ and $BR_K \ \cap \ BR_L : BR$) could yield Nash equilibria in mixed strategies, since outside the intersection for at least one of the players one of the strategies is strictly dominated by the other strategy.

Figure 4: Areas where priors matter



For example, in the present context ($CV_K < CV_L$), when $\delta_1 < r$, for player L strategy C is a strictly dominating strategy for values of δ_2 below CV_L. This implies that between CV_K and CV_L player K has to compare $u_K(C, C)$ and $u_K(F, C)$. Given the fact that we are considering the case where $\delta_1 < r$, and given the fact that player L's '*undominated strategy space*' is singleton $\{C\}$, we see that player K's strategy will not depend on his priors anymore either: strategy C strictly dominates strategy F. The analysis is analogous for $r < \delta_1$: for values of δ_2 between

CV_K and CV_L, player K's '*undominated strategy space*' becomes singleton $\{F\}$. Hence, player L's strategy choice is determined by the trade-off between $u_L(F,C)$ and $u_L(F,F)$, which is equivalent to comparing δ_2 with $(r-\alpha)/\big[(1-P)(1-\alpha)+P(r-\alpha)\big]$. This implies that for $\delta_2 > CV_L$ player L will choose strategy F, otherwise strategy C is the dominant strategy.

4.2 Strategic behavior

Clearly, the strategy-choice depends on the *expected* utility of both strategies. Players use their *probability beliefs* (cf. Nash equilibria: section 3) on the opponent's willingness to cooperate to assess the expected utility of their own respective strategies[16]:

$$\begin{cases} u^e_K(C,\cdot) &= \pi^e_{L_C} rY_R + (1-\pi^e_{L_C})\left[\frac{r-(1-\alpha)}{\alpha}\right]\delta_1 Y_R \\ u^e_K(F,\cdot) &= \pi^e_{L_C}\delta_1 Y_R + (1-\pi^e_{L_C})\left[\frac{P\alpha+(1-P)[r-(1-\alpha)]}{\alpha}\right]\delta_1\delta_2 Y_R. \end{cases}$$

Solving the equation $u^e_K(C,\cdot) = u^e_K(F,\cdot)$ shows that player K will be indifferent to his two strategies for:

$$\pi^e_{L_C} = \pi^*_{L_C} = \frac{\big(P\alpha+(1-P)[r-(1-\alpha)]\big)\delta_1\delta_2 - [r-(1-\alpha)]\delta_1}{\alpha(r-\delta_1) + \big(P\alpha+(1-P)[r-(1-\alpha)]\big)\delta_1\delta_2 - [r-(1-\alpha)]\delta_1}.$$

Not surprisingly, but worth noting, we see that $0 < \pi^*_{L_C} < 1$ only when $\delta_1 < r \,\cap\, CV_K < \delta_2$ or when $r < \delta_1 \,\cap\, \delta_2 < CV_K$ (i.e. TL_K and BR_K). The same holds for player L: $0 < \pi^*_{K_C} < 1$ only holds in the TL_L- and BR_L-area. Indeed, outside these areas the strategy does not depend on *beliefs* anymore. We can easily see that $u^e_K(C,\cdot) > u^e_K(F,\cdot)$ when $\delta_1 < r \,\cap\, \delta_2 < CV_K$, whatever the value of $\pi^e_{L_C}$. Similarly, whatever the value of $\pi^e_{L_C}$, when $r < \delta_1 \,\cap\, CV_K < \delta_2$ we see that $u^e_K(F,\cdot) > u^e_K(C,\cdot)$[17].

We can express the equation for π^*[18] in terms of the expected utilities:

$$\pi^*_{L_C} u_K(C,C) + (1-\pi^*_{L_C})u_K(C,F) = \pi^*_{L_C} u_K(F,C) + (1-\pi^*_{L_C})u_K(F,F).$$

By rearranging terms we get:

$$\pi^*_{L_C}\Big[u_K(C,C) - u_K(F,C)\Big] + (1-\pi^*_{L_C})\Big[u_K(C,F) - u_K(F,F)\Big] = 0.$$

Using the expressions for $u_H(X,Y)$, this is equivalent to:

$$\pi^*_{L_C}\Big[r-\delta_1\Big]Y_R + (1-\pi^*_{L_C})\Big[[r-(1-\alpha)]\delta_1 - \big(P\alpha+(1-P)[r-(1-\alpha)]\big)\delta_1\delta_2\Big](Y_R/\alpha) = 0.$$

In these equations we can interpret the first term, $\pi^*_{L_C}[u_K(C,C) - u_K(F,C)]$, as *'the expected advantage of cooperating when the other player cooperates'* and the second term, $(1-\pi^*_{L_C})[u_K(C,F) - u_K(F,F)]$, as *'the expected advantage of cooperating when the other player fights'*. This formulation eases the interpretation of what happens if $\pi^e_{L_C}$ is different from $\pi^*_{L_C}$. Since the interpretation differs depending on the area in the $\delta_1\delta_2$-square, we analyze them separately.

TL_K-AREA. The area is defined by $\delta_1 < r \,\cap\, CV_K < \delta_2$. This implies that $u_K(C,C) > u_K(F,C)$ and $u_K(C,F) < u_K(F,F)$ (cf. section 3.1), meaning that *'the expected advantage of cooperating when the other player cooperates'* is positive while *'the expected*

[16] Although we consider player K, the analysis for player L is analogous.

[17] Outside TL_H and BR_H player H's ($\forall H \in \{K,L\}$) probability of playing a particular strategy is 1.

[18] $\pi^*_{L_C}$ is the value of π_{L_C} that yields a Nash equilibrium in mixed strategies.

advantage of cooperating when the other player fights' is negative[19]. In order to be indifferent between his two strategies, player K needs $\pi^e_{L_C} = \pi^*_{L_C}$. When, for example, $\pi^e_{L_C} > \pi^*_{L_C}$, we can see that the first term, the positive one, will be given more weight than if player K were indifferent, meaning that the *'expected advantage of cooperating'* is positive ($\pi^e_{L_C}[u_K(C,C) - u_K(F,C)] + (1-\pi^e_{L_C})[u_K(C,F) - u_K(F,F)] > 0$). Hence, for $\pi^e_{L_C} > \pi^*_{L_C}$ player K will choose strategy C, while for $\pi^e_{L_C} < \pi^*_{L_C}$ he will choose strategy F.

BR_K-AREA. Here we know that $r < \delta_1$ and that $\delta_2 < CV_K$. This implies that $u_K(C,C) < u_K(F,C)$ and that $u_K(C,F) > u_K(F,F)$, meaning that *'the expected advantage of cooperating when the other player cooperates'* is *negative* while *'the expected advantage of cooperating when the other player fights'* is *positive*. Again, in order to be indifferent between his two strategies, player K needs $\pi^e_{L_C} = \pi^*_{L_C}$. However, when $\pi^e_{L_C} > \pi^*_{L_C}$, we can see that the first term, the negative one, will be given more weight than it would if player K would be indifferent. This means that the *'expected advantage of cooperating'* is negative ($\pi^e_{L_C}[u_K(C,C) - u_K(F,C)] + (1-\pi^e_{L_C})[u_K(C,F) - u_K(F,F)] < 0$). Hence, for $\pi^e_{L_C} > \pi^*_{L_C}$ player K will choose strategy F.

As we demonstrate in figure 5, combining these findings with the analysis in section 3.1 allows us to characterize all the equilibria within figure 1, for different values of $\pi^e_{L_C}$ and $\pi^e_{K_C}$. This yields four panels: panel **i** in which there is high mutual trust, panel **iv** in which mutual trust is low, and panel **ii** and **iii** showing a case in which one player has a high trust level, while the other has a low trust level.

4.3 The cost of 'defection'

Some comparative statics show us what happens when the relative payoffs change. For this we examine the impact of shocks in 'the costs of defection'[20] (δ_1, δ_2) within the TL- and BR-area. Furthermore, it can be easily demonstrated that changes in P generate comparable results as changes in the δ's. Taking the first derivatives of π^* with respect to δ_1, δ_2 and P, we obtain:

$$\begin{aligned}
\partial\pi^*_{L_C}/\partial\delta_1 &= \frac{\alpha r\left[\left(P\alpha+(1-P)[r-(1-\alpha)]\right)\delta_2-[r-(1-\alpha)]\right]}{\left[\alpha(r-\delta_1)+\left(P\alpha+(1-P)[r-(1-\alpha)]\right)\delta_1\delta_2-[r-(1-\alpha)]\delta_1\right]^2}\\
\partial\pi^*_{L_C}/\partial\delta_2 &= \frac{\alpha\left(P\alpha+(1-P)[r-(1-\alpha)]\right)\delta_1\left[r-\delta_1\right]}{\left[\alpha(r-\delta_1)+\left(P\alpha+(1-P)[r-(1-\alpha)]\right)\delta_1\delta_2-[r-(1-\alpha)]\delta_1\right]^2}\\
\partial\pi^*_{L_C}/\partial P &= \frac{\alpha\delta_1\delta_2(1-r)\left[r-\delta_1\right]}{\left[\alpha(r-\delta_1)+\left(P\alpha+(1-P)[r-(1-\alpha)]\right)\delta_1\delta_2-[r-(1-\alpha)]\delta_1\right]^2}.
\end{aligned}$$

In figure 6 we show the impact of an increase in δ_1, δ_2 and P on π^*[21]. We interpret the interaction between the δ's and π^* as the relationship between the 'critical level of trust'[22] (π^*) and the costs of 'non-cooperation/defection' (δ_1, δ_2). Furthermore, we interpret changes in P as shocks in 'relative power'.

We know that π^* depends on δ_1, δ_2 and P, and we assume that π^e does not, which reflects the fact that we treat the level of trust between the two groups as exogenous.

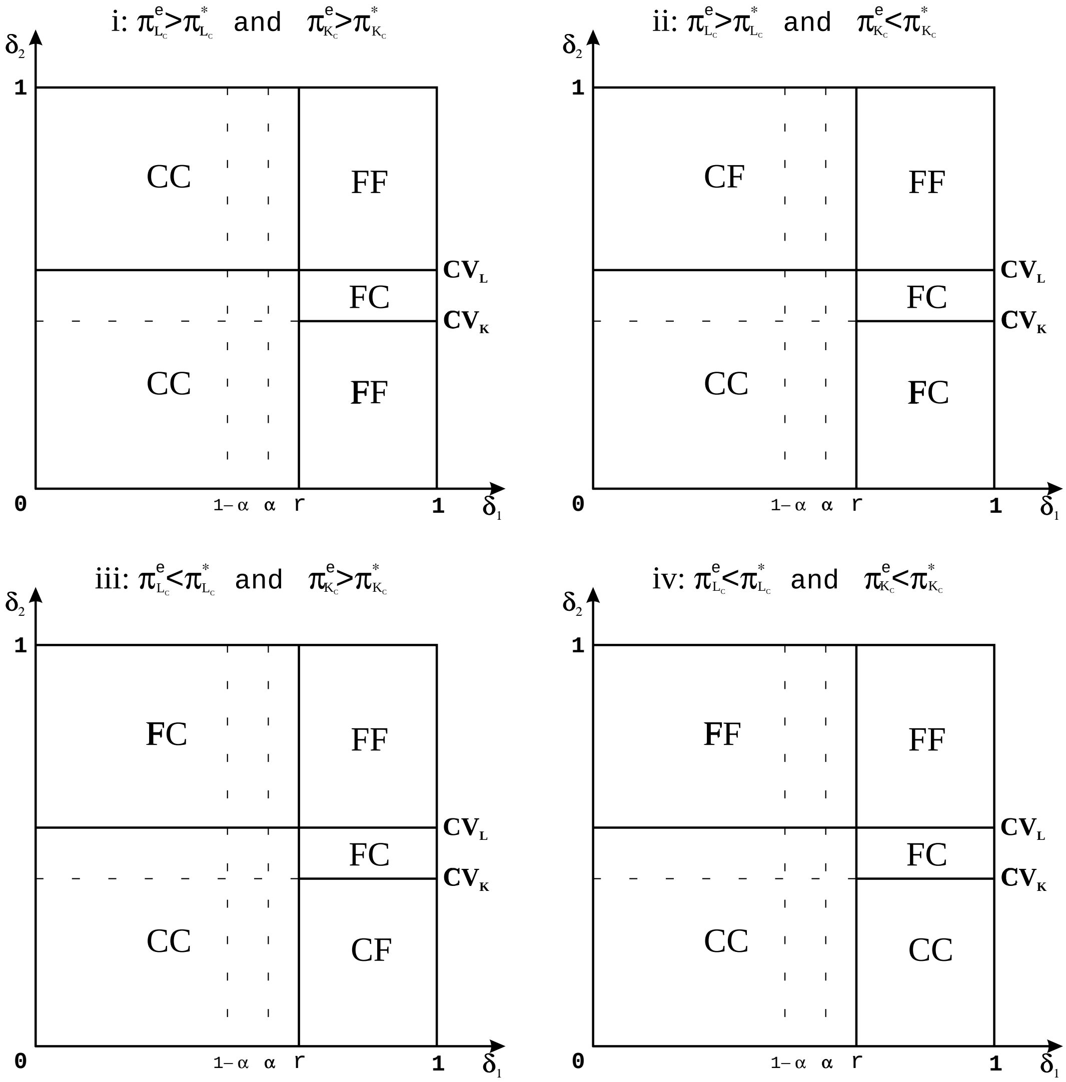
[19] To guarantee indifference of player K between his two strategies, in absolute value these two terms should be equal to each other.

[20] By defection we mean that at least one player chooses not to cooperate.

[21] Note that for reasons mentioned earlier (cf. section 4.2) we restrict the analysis to the TL and BR area, even though $\Delta\delta_1$ and $\Delta\delta_2$ could get us out of these areas.

[22] The 'level of trust' in our model is the *belief* one player has about the other player's probability of choosing strategy C, namely, the degree to which a player is confident the other player will be cooperative.

Figure 5: Types of equilibria for given priors

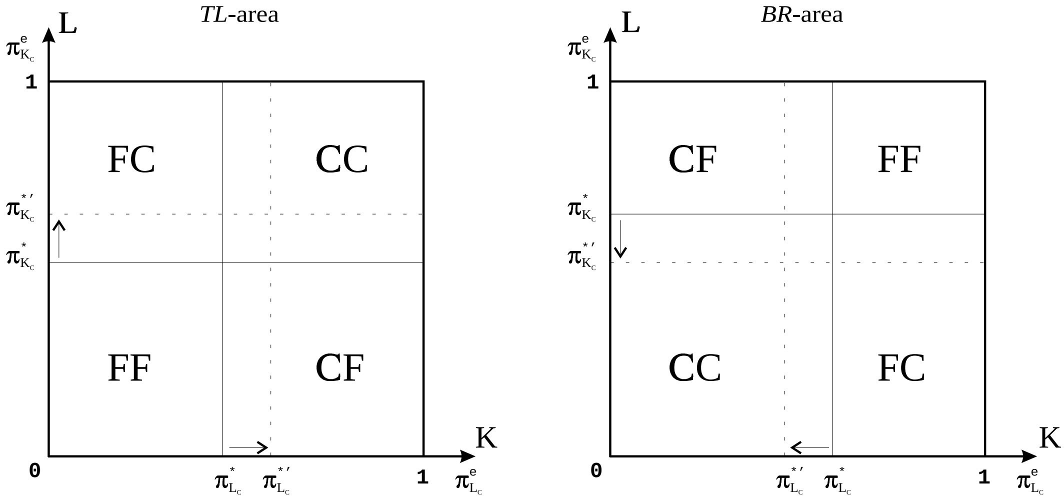


As we can see from $\partial\pi^*_{LC}/\partial\delta_1$, $\partial\pi^*_{LC}/\partial\delta_2$ and $\partial\pi^*_{LC}/\partial P$, the impact of $\Delta\delta_1$, $\Delta\delta_2$ and ΔP on π^*_{LC} in the TL area is opposite to the one in the BR area.

TL_K-AREA. Increases in δ_1, δ_2 or P induce a rise of π^*_{LC}: $\partial\pi^*_{LC}/\partial\delta_1 > 0$, $\partial\pi^*_{LC}/\partial\delta_2 > 0$ and $\partial\pi^*_{LC}/\partial P > 0$. This means that, for a player to choose strategy C with decreased costs of 'not cooperating' ($\Delta\delta > 0$) or risen relative power ($\Delta P > 0$), a higher level of trust (π^e) will be required, which is a very intuitive outcome.

BR_K-AREA. Here, the impact of changes in the δ's and P on π^*_{LC} is opposite: $\partial\pi^*_{LC}/\partial\delta_1$, $\partial\pi^*_{LC}/\partial\delta_2$ and $\partial\pi^*_{LC}/\partial P$ all are < 0. This too generates an intuitive result: given the fact that in the BR-area, when $\pi^e > \pi^*$, a player will choose strategy F (cf. section 4.2), for a player to choose the cooperative strategy with decreased costs of 'defection' or risen relative power, a higher level of trust will be required.

Figure 6: Impact of $\Delta\delta_1 > 0$; $\Delta\delta_2 > 0$ (and $\Delta P > 0$)



4.4 Overview of the model

From section 3 we know that in the TL and BR area three potential Nash equilibria exist: two in pure strategies, and one in mixed strategies. The principal contribution of this section is the interpretation of situations where actions and beliefs do not coincide: within the 'Nash-equilibrium-framework', we present an intuitive interpretation of out-of-equilibrium situations.

This analysis generates clear predictions in the undetermined areas, depending on his level of trust (π^e), relative to some 'critical level' (π^*), which is the level of trust that would result in a Nash equilibrium in mixed strategies. Thereby, even incorrect assessments of the opponent can lead to an equilibrium, which is a 'relaxation' of the Nash-equilibrium analysis that is quite plausible in one-shot games[23].

From the preceding analysis we see that, both in TL and BR, to reach the cooperative equilibrium, i.e. a fully integrated society, with a low 'cost of defection', the reciprocal level of trust will need to be high, which implies that, in countries where fighting hardly harms national production, the level of inter-ethnic (or inter-religious ...) trust matters more.

Now, if we assume that fighting is least harmful/detrimental to the national product of a 'primary-commodity-dependent' economy (cf. supra), it follows that these economies will require high levels of inter-ethnic trust in order to reach group cooperation.

Furthermore, we show that changes in P generate similar effects to changes in the δ's. This would imply that trust levels that prompted cooperative behavior beforehand, could elicit fighting after the rise of P. Or, in other words, if one group gets relatively stronger, the minimal required level of trust for which that group cooperates will rise.

Finally, the three main cases of our analysis clearly demonstrate that when poverty is very high (case 3: $r < (1-\alpha) < \alpha$), for the country to reach the cooperative equilibrium, the level of inter-ethnic trust will be the key issue.

[23] In repeated games, expectations should be endogenous. The need to endogenize expectations is clear from figure 5: if we take for example panel **ii**, player K has a lot of trust that L will cooperate, while L has little trust that K will cooperate. These expectations are not confirmed by the resulting strategies, on the contrary.

5 Conclusions

The model considers centrally governed regions or countries, which are populated by two social groups (this could reflect ethnic, religious or social class diversity). The degree of diversity is not specified, it can be very high or very low. Furthermore, the model assumes that national income is optimized when (economic) group behavior is not affected by social affiliation: when agents preferably or solely interact with agents of the same (social) group, this is assumed to limit the economic potential of the region. Then, a fundamental assumption is that the degree to which limited interaction restrains economic output differs among countries: when national income primarily depends on revenues from exploitation of natural resources, we assume that interaction matters less than in, for example, a service-industry oriented economy.

Within this framework we show that whether interaction will be 'hampered' by ethnic, religious or social affiliations could depend on the country's degree of poverty (the percentage of *subsistence* jobs), and on the impact non-cooperation has on national income (the extent to which national income depends on 'economic interaction').

This could explain why some regions fail to develop a 'growth-promoting' institutional framework: the economic activity of many of the lagging countries seems to depend on the exploitation of natural resources (cf. section 1). Since this type of economic activity is typically characterized by a low amount of *rewarding* jobs and a low cost of non-cooperation, '*cooperating*' might not be an equilibrium strategy among (socially diverse) groups. In other words, we show that segregation (based on, e.g., ethnicity) could come as a 'convenient excuse', hiding economic motives: under some circumstances it proves to be a utility-maximizing and equilibrium strategy to let for example ethnic affiliation guide economic interaction.

Finally, we demonstrate the importance of inter-group trust. While it is clear that cooperative behavior is encouraged by high levels of trust, our model shows that under some circumstances (e.g. strong 'resource dependence') even high trust-levels will be insufficient to incite cooperative behavior among groups. When national income is easily (i.e. relatively costlessly) creamed off, even high levels of inter-group trust can not guarantee cooperative group behavior.

A Elaboration of the five omitted cases

A.1 $(1-\alpha) = \alpha = 1/2 < r$

This case is very similar to case 1, except of course the fact that we consider equally sized groups. The (per capita) payoffs are (note that $\alpha = 1/2$):

$$
\begin{array}{ll}
u_K(C,C) = rY_R & u_L(C,C) = rY_R \\
u_K(C,F) = \left[\frac{r-\alpha}{\alpha}\right]\delta_1 Y_R & u_L(C,F) = \delta_1 Y_R \\
u_K(F,C) = \delta_1 Y_R & u_L(F,C) = \left[\frac{r-\alpha}{\alpha}\right]\delta_1 Y_R \\
u_K(F,F) = \left[\frac{P\alpha+(1-P)[r-\alpha]}{\alpha}\right]\delta_1\delta_2 Y_R & u_L(F,F) = \left[\frac{(1-P)\alpha+P(r-\alpha)}{\alpha}\right]\delta_1\delta_2 Y_R
\end{array}
$$

In this case, CV_K and CV_L become:

$$
\begin{aligned}
CV_K &= [r-\alpha]/\big[P\alpha + (1-P)[r-\alpha]\big] \\
CV_L &= (r-\alpha)/\big[(1-P)\alpha + P(r-\alpha)\big].
\end{aligned}
$$

A.2 $(1-\alpha)=\alpha=r=1/2$

The outcomes in this case are similar to those in case 3. The (per capita) payoffs are (again, $\alpha = 1/2$):

$$\begin{aligned} u_K(C,C) &= rY_R & u_L(C,C) &= rY_R \\ u_K(C,F) &= 0 & u_L(C,F) &= \delta_1 Y_R \\ u_K(F,C) &= \delta_1 Y_R & u_L(F,C) &= 0 \\ u_K(F,F) &= P\delta_1\delta_2 Y_R & u_L(F,F) &= (1-P)\delta_1\delta_2 Y_R \end{aligned}$$

The critical values, CV_K and CV_L, are both 0.

A.3 $r<(1-\alpha)=\alpha=1/2$

Again, we can refer to case 3 of the paper. The (per capita) payoffs are ($\alpha = 1/2$):

$$\begin{aligned} u_K(C,C) &= rY_R & u_L(C,C) &= rY_R \\ u_K(C,F) &= 0 & u_L(C,F) &= \left[\tfrac{r}{\alpha}\right]\delta_1 Y_R \\ u_K(F,C) &= \left[\tfrac{r}{\alpha}\right]\delta_1 Y_R & u_L(F,C) &= 0 \\ u_K(F,F) &= \left[\tfrac{Pr}{\alpha}\right]\delta_1\delta_2 Y_R & u_L(F,F) &= \left[\tfrac{(1-P)r}{\alpha}\right]\delta_1\delta_2 Y_R \end{aligned}$$

And again, the critical values are both 0.

A.4 $(1-\alpha)<\alpha=r$

This is a case similar to case 2 in the paper. The (per capita) payoffs are:

$$\begin{aligned} u_K(C,C) &= rY_R & u_L(C,C) &= rY_R \\ u_K(C,F) &= \left[\tfrac{r-(1-\alpha)}{\alpha}\right]\delta_1 Y_R & u_L(C,F) &= \delta_1 Y_R \\ u_K(F,C) &= \delta_1 Y_R & u_L(F,C) &= 0 \\ u_K(F,F) &= \left[\tfrac{P\alpha+(1-P)[r-(1-\alpha)]}{\alpha}\right]\delta_1\delta_2 Y_R & u_L(F,F) &= (1-P)\delta_1\delta_2 Y_R \end{aligned}$$

And we calculate the values for CV_K and CV_L:

$$\begin{aligned} CV_K &= [r-(1-\alpha)]/\{P\alpha+(1-P)[r-(1-\alpha)]\} \\ CV_L &= 0. \end{aligned}$$

A.5 $(1-\alpha)=r<\alpha$

Finally, this case is practically identical to case 3, with (per capita) payoffs:

$$\begin{aligned} u_K(C,C) &= rY_R & u_L(C,C) &= rY_R \\ u_K(C,F) &= 0 & u_L(C,F) &= \delta_1 Y_R \\ u_K(F,C) &= \left[\tfrac{r}{\alpha}\right]\delta_1 Y_R & u_L(F,C) &= 0 \\ u_K(F,F) &= \left[\tfrac{Pr}{\alpha}\right]\delta_1\delta_2 Y_R & u_L(F,F) &= (1-P)\delta_1\delta_2 Y_R \end{aligned}$$

And critical values are 0.

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